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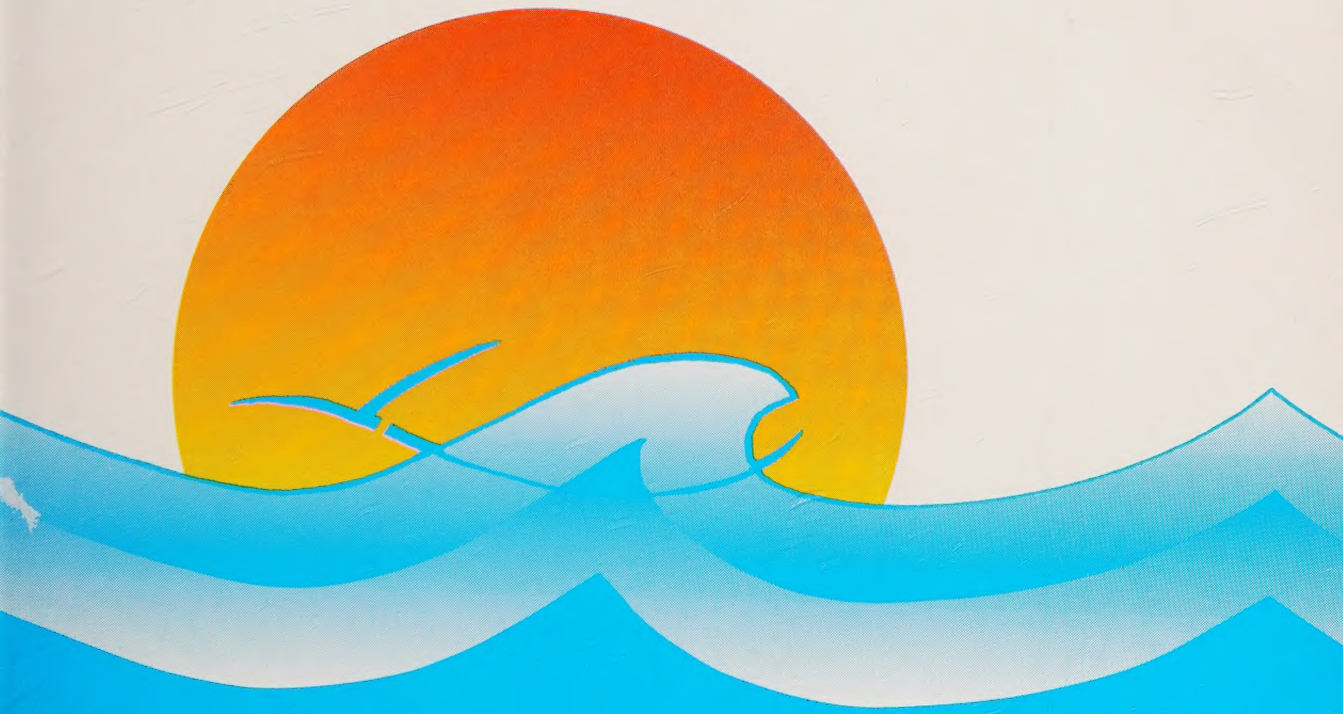

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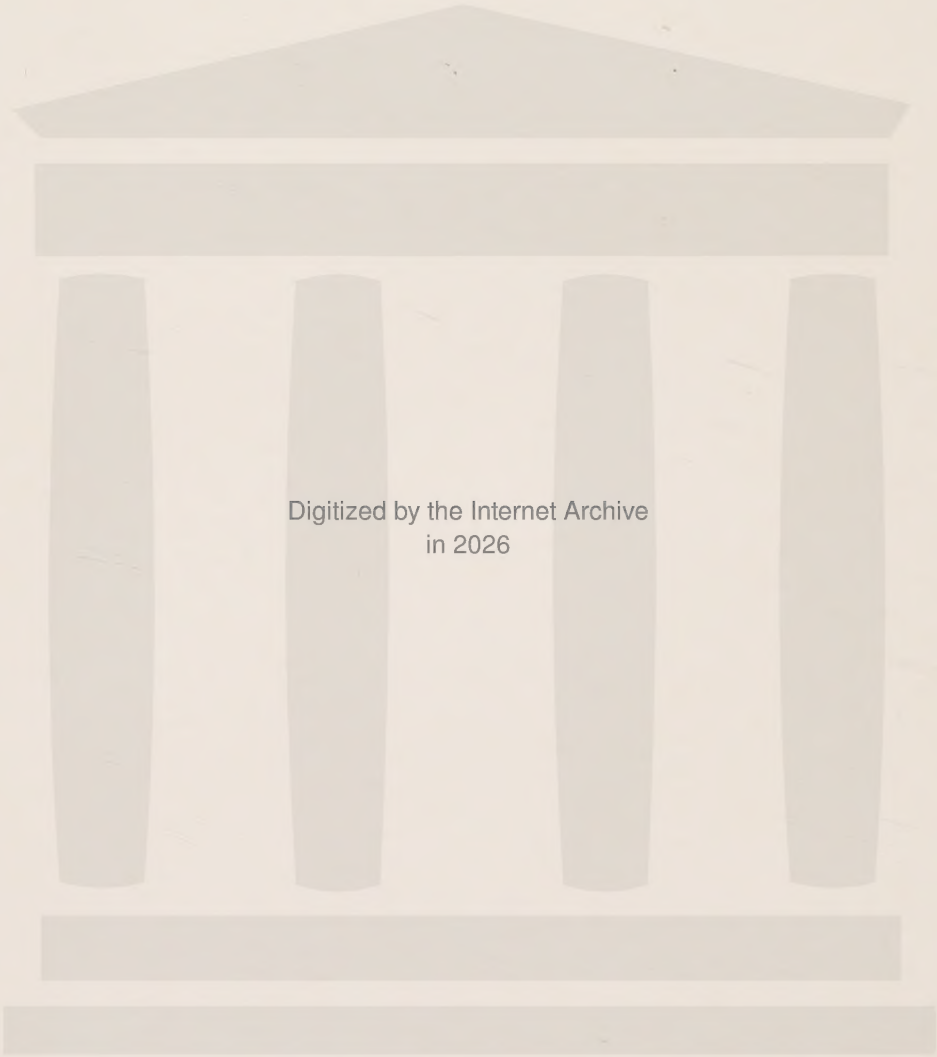

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CONTENTS

Mission of the Sea Fisheries Research Institute

1. Introduction 1

2. Studies on resources 3

2.1 Pelagic fish 3
2.2 Horse mackerel 6
2.3 Demersal fish 7
2.4 Linefish 10
2.5 Squid 11
2.6 Abalone 13
2.7 Rock lobster 13
2.8 Seaweed 16

3. Environmental and ecological studies 18

3.1 Red tide 18
3.2 Plankton-fish trophic interactions 19
3.3 Fish behaviour 20
3.4 Mariculture-environment interactions 21
3.5 Marine mammals 23
3.6 Seabirds 24
3.7 Agulhas Bank productivity 25
3.8 Southern Ocean 26

4. Some technological advances 27

4.1 Measuring ocean currents 27
4.2 Acoustic technology 27

5. Publications 29

5.1 Publications involving staff and directly contracted staff 29
5.2 Contributions by outside authors 33

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MISSION OF THE SEA FISHERIES RESEARCH INSTITUTE

The Sea Fisheries Research Institute advises on the optimal utilization of living marine resources and the conservation of marine ecosystems by conducting and supporting relevant multidisciplinary scientific research and monitoring in the marine environment. Sustainable utilization and the need to preserve future options regarding the utilization of marine ecosystems and their resources are guiding objectives in the research and advice of the Institute. In order to achieve its goals, the Institute advises and interacts with decision-makers, the fishing industry, interest groups and the local and international scientific community. The Institute conducts its activities in an open and cooperative manner, functions within the Department of Environment Affairs and strives for excellence in its research and advice.

1. INTRODUCTION

THE Sea Fisheries Research Institute has completed its first year of functioning within a matrix-type structure, details of which were provided in the first issue of *Research Highlights*. The transition was smooth, partly because the working group concept had to be implemented on an experimental basis a few years before the functional group changes, which enabled teething problems to be ironed out with ease, but mainly because of the enthusiastic and mature response of Institute staff. The team spirit which prevails in the organization and the excellent cooperation which exists between ourselves and outside bodies are factors central to the Institute providing a cost-effective service and appropriate scientific advice needed for the wise management of South Africa's living marine resources.

This, the second issue of *Research Highlights*, follows the format introduced last year. Again, it is not a record of all the Institute's activities, but rather highlights the principal issues and topical items. It does however differ from the first issue in that a section on technological advances has been incorporated. In this respect the R & D work undertaken by the Institute's Engineering Services and Technical Management and Development groups has contributed materially to the improved efficiency and cost-effectiveness of a number of field operations which support the research and assessment functions. Perhaps the most significant of these has been the development over the years of an advanced hydroacoustic assessment capability by the Institute, a capability which has underpinned the scientific advice provided on South Africa's pelagic fish resources in particular. This capability is now being extended to horse mackerel *Trachurus trachurus capensis* (the first successful direct survey of which was undertaken in the spring of 1992) and applied to studies of fish behaviour, an important area which had been neglected until very recently.

With the recovery of the South African pilchard or sardine *Sardinops sagax* now becoming more obvious as a consequence of the management policy which has been in place for a number of years, the by-catch of this species is posing a major operational problem for the pelagic fleet targeting on anchovy *Engraulis capensis*. As a response, work has started on the development of a multispecies approach for the management of pelagic fish, but it is likely that it will still be a year or two before the modelling is sufficiently advanced to permit its implementation with an acceptable level of risk.

It would be inappropriate for me to attempt to highlight the highlights. Nevertheless, I do wish to draw the readers' attention to some of the significant advances, viz.: the encouraging results from the work on biochemical indicators (predictors) of growth of male West Coast rock lobster *Jasus lalandii*; the results of the *Gracilaria* transplant experiment and the growth rates of 13% per day recorded for these transplanted plants; encapsulation of the results of South African linefish research as articulated in the new regulations announced in 1992; the results of the latest studies on hake *Merluccius* spp. diet on the South Coast; the tentative results linking the fluctuations of pelagic stocks with structural changes in plankton assemblages resulting from changes in the physical environment; the well-integrated study on chokka squid *Loligo vulgaris reynaudii* and its environment on the South Coast; the finding that there is significant (21–30%) mortality of young pups in the colony of South African fur seals *Arctocephalus pusillus pusillus* at Kleinsee; the links between abundance of pelagic species and seabird populations and the need to ensure that predators such as the African

penguin *Spheniscus demersus* can get their share of the fish; the international importance of the Institute's research in the Southern Ocean, albeit very limited, for the conservation of krill *Euphausia superba* and the species which depend on this crustacean; and the Institute's embryonic research on the mariculture carrying capacity. In almost all these activities the Institute has worked in partnership with outside scientists and the fishing industry.

Before concluding it would be appropriate to mention two important initiatives which have relied on public participation, namely the telephone surveys conducted to establish the level of the recreational catches of rock lobster and abalone *Haliotis midae*. For the first time we now have fairly reliable estimates of these recreational catches — 160 tons of rock lobster and 368 tons of abalone in the 1991/92 season, the latter being equivalent to 62% of the commercial harvest.

What is perhaps not all that obvious from a casual glance at this issue of *Research Highlights*, but which does emerge when studied in more detail, is the growing tendency for the Institute to function in partnership with outside scientists, research organizations, the fishing industry and the general public. This encouraging trend, together with the increasing transparency of our operation, is obviously beneficial to all parties involved, and most of all to the taxpayers and to those who are entrusted with husbanding the living marine resources for the use and benefit of present and future generations of South Africans.

* * *

2. STUDIES ON RESOURCES

2.1 Pelagic fish

THE relatively short lifespan of pelagic fish and the high variability in annual recruitment ensure that the unexpected in the population dynamics of these species is normal. One such surprise was the major recovery in the anchovy biomass from November 1990 to November 1991. A number of possible explanations were put forward for the record recruitment leading to this recovery. Good feeding conditions on the spawning grounds of the western Agulhas Bank during the 1990/91 spawning season, coupled with low densities of anchovy then, should have allowed sustained high production of eggs. Simultaneously, the cool ridge of water over the central and eastern Bank, which normally prevents spawning close inshore, was less prominent, allowing the fish to spawn over a wider area. These favourable conditions were accompanied by a high biomass of plankton in the nursery areas along the West Coast, allowing rapid growth of juveniles. All these factors could have contributed to very high recruitment.

Following the recovery of the population, there was considerable interest in the recruitment survey undertaken in May 1992. The results of that survey indicated that recruitment was close to the observed average value for the past eight years and the Total Allowable Catch (*TAC*) was subsequently increased from the 270 000 tons set in January 1992 to 350 000 tons. An unusual feature of this survey was the number of small anchovy on the South Coast, and there is some doubt as to the actual age of those fish. An urgent re-evaluation of the ageing criteria used for anchovy and pilchard is currently under way, and the results of this will be available towards the end of 1993.

Despite the uncertainties, the November 1992 survey largely confirmed the finding of the recruitment survey, the biomass of anchovy being at the still good level of approximately 1 500 000 tons (Fig. 1), enabling a *TAC* of 260 000 tons to be set in January 1993. The

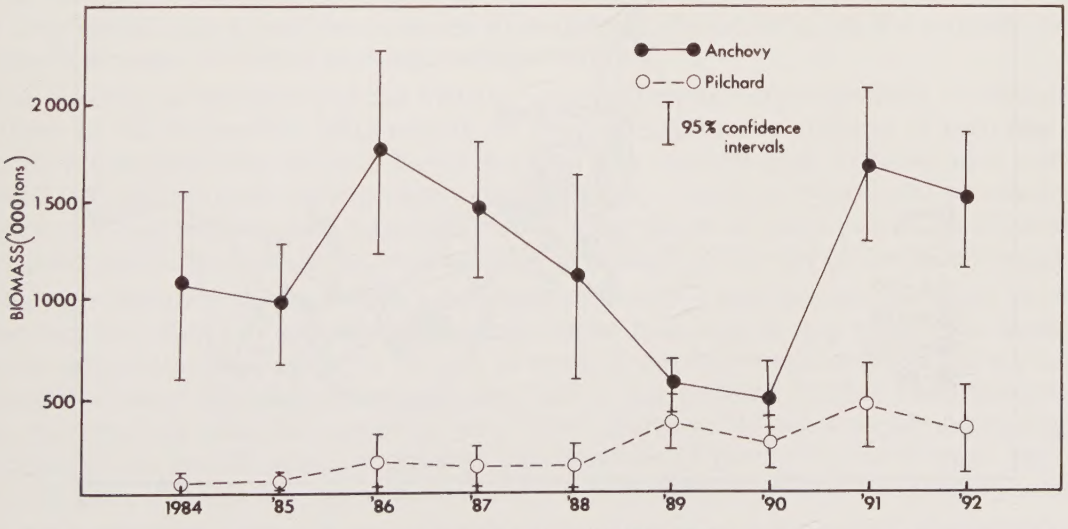

Fig. 1: Biomass estimates of anchovy and pilchard from 1984 to 1992 from hydroacoustic surveys undertaken in November each year. The vertical bars indicate the 95% confidence limits

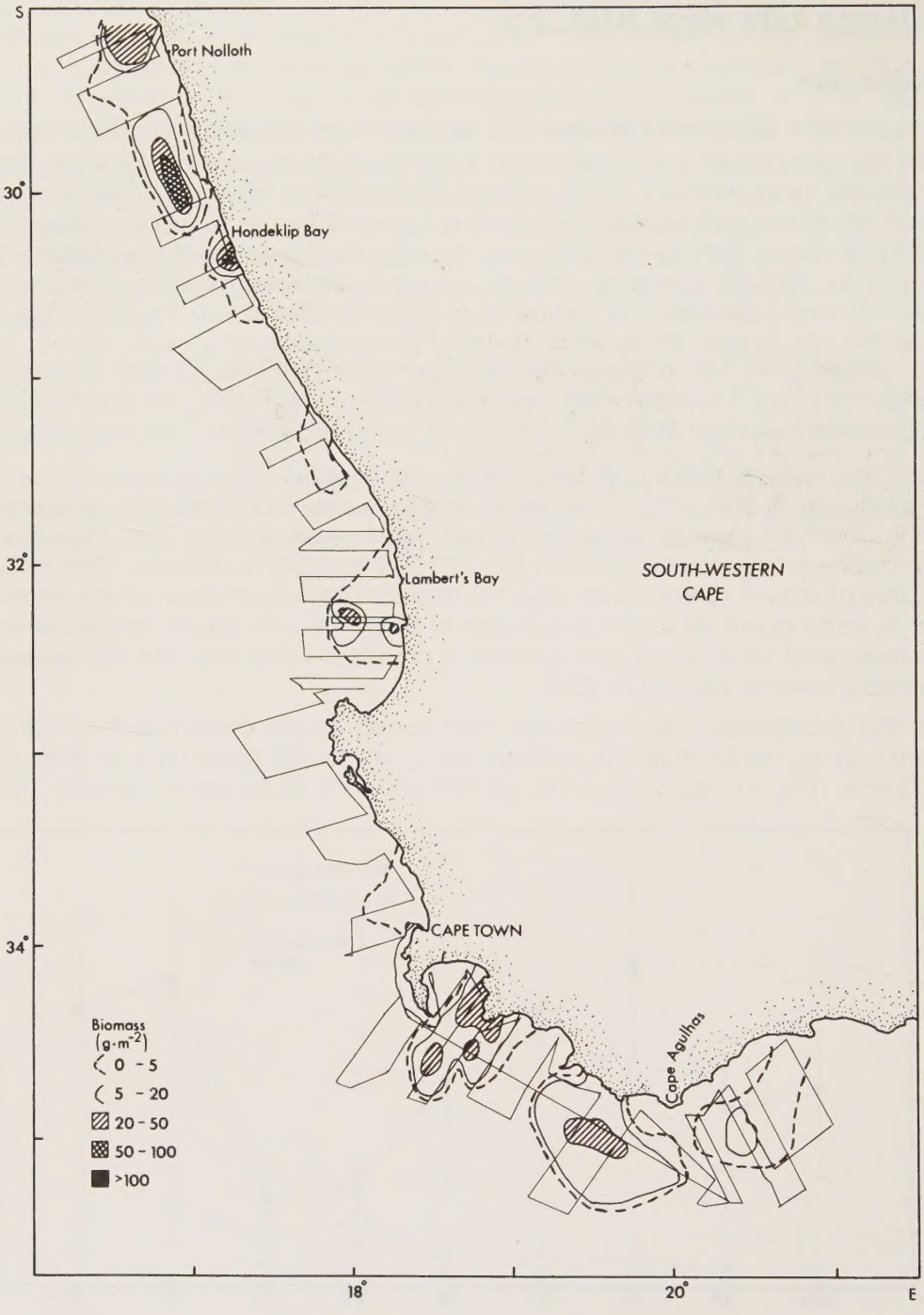

Fig. 2: The distribution of pilchard during the hydroacoustic recruitment survey of May 1992

January *TAC* is, by design, normally conservative and, if recruitment is close to average or better, there would likely be an increase after the May recruitment survey.

A re-assessment of anchovy population dynamics, including the latest data, was undertaken during 1992, and it was found that variability in recruitment may be even higher than previously thought. This leads to the finding that the risk of the population falling to low levels, at which stock-recruit effects could be expected, is probably substantially higher than previously estimated, both with and without fishing. This result may indicate the need for a re-examination of acceptable risk levels in the formulation of a new management procedure. In the same study, good progress has also been made in liaising with representatives of the fishing industry to identify the optimal constraints, such as minimum and maximum *TAC*s, for protection of the resource and efficient management of the fishery.

The pilchard results of the May 1992 survey also raised as many questions as they answered. The results of the survey showed the highest numbers of pilchard recruits yet measured on a recruitment survey; they were also very widespread (Fig. 2). There was therefore considerable optimism about pilchard before the November 1992 survey of adult pelagic fish which, unfortunately, was not fulfilled. Indeed, the pilchard biomass was estimated on that survey to have fallen slightly in comparison to that of the previous November (Fig. 1). The confidence intervals for both surveys were relatively broad and this may explain the discrepancy between the two results. Other possible explanations were that there was high mortality of juvenile pilchard during the second half of the year, or that there was a high mortality of adults during the year. The two 1993 surveys should throw some light on these theories.

The large by-catch of juvenile pilchard in anchovy catches has frequently curtailed pelagic fishing operations and, in 1992, led to the pilchard *TAC* being exceeded by some 15%. The biological and socio-economic ramifications of this problem are recognized and a multi-species approach, in which *TAC*s for both species will be taken into account, is currently being investigated. A disturbing aspect of the problem is that rumours continue to circulate about substantial dumping of "unwanted" by-catches of juvenile pilchard. Such an activity is not only illegal, but it has the potential to negate all the benefits, to the industry and the pilchard resource, of careful resource management.

The histological laboratory at the Institute underwent major improvements, so delaying the analysis of the November 1992 results for the egg production method of biomass determination. Considerable effort is being put into this method and, in November 1992, the CalVET net was mounted independently of the Bongos in order to reduce any oversampling of eggs which may have caused a positive bias of this method in recent years. Investigations are also being conducted into an improved means of estimating the rate of mortality of eggs.

The high variability in recruitment, particularly of anchovy, and its implications for the fishery, mean that any ability to estimate recruitment earlier than May in any given year would be a definite advantage. One possible method of doing this is by means of prerecruit surveys; the second dedicated anchovy prerecruit survey took place in March 1992. It was more extensive than the previous one and sampling was more intensive. These changes led to improved precision of the results, which suggested that densities of prerecruits were lower than in the previous year. This was not inconsistent with the results of the respective recruitment surveys.

Another possible approach to forecasting recruitment is with the use of environmental and biological indicators. There is currently good conceptual understanding of the factors limiting

anchovy recruitment, but there is still a long way to go before this can be translated into predictive relationships or rules. In conjunction with the Benguela Ecology Programme, a major exercise, the Sardine and Anchovy Recruitment sub-Programme (SARP), is planned for the next two spawning seasons. This sub-programme aims to monitor and investigate within-season variability in spawning of anchovy and pilchard, the distribution and transport of eggs and larvae, the growth of larvae and juveniles and the environmental and ecological factors regulating these events. It is hoped that the result will be greater insight into the factors which regulate recruitment success each year.

Zooplankton form the primary food of anchovy, and monitoring zooplankton abundance is a central part of SARP. It is, however, very time-consuming. Investigations are currently under way to improve estimates of zooplankton biomass and abundance by means of hydro-acoustic technology. This would be dependent on the existence of a precise relationship between zooplankton biomass and abundance, as estimated from net hauls, and acoustic volume back-scattering strength. Preliminary results suggest that the objective is feasible, and further work is under way to improve the quality of the relationships (Fig. 3).

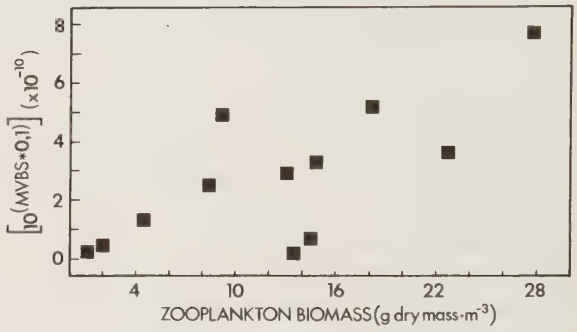

Fig. 3: Scatterplot of acoustic volume back-scattering strength against zooplankton biomass

2.2 Horse mackerel

RESEARCH on the horse mackerel has focused on the need for a scientifically based *TAC* for the resource. Modelling of the resource is hampered severely by the lack of a high quality long-term data series. Consequently, little faith is placed on the results of the surplus production model. Research during 1992 concentrated on obtaining an accurate *in situ* estimate of acoustic target strength (*TS*) for horse mackerel and an acoustic estimate of horse-mackerel biomass.

The first in a programme of annual acoustic surveys of the horse-mackerel stock on the South Coast was successfully completed during October 1992. The accuracy of acoustic estimates of biomass are influenced by the accuracy of the estimated *TS* for the species; there is no available estimate of *TS* for any species of horse mackerel. A programme to estimate acoustic target strength *in situ*, using split-beam technology, was therefore developed and tested. Reliable *TS* estimates for horse mackerel were obtained during the October 1992 survey and the Institute is now in a position to calculate reliable acoustic estimates of abundance of horse mackerel.

The $TS \cdot kg^{1}$ for a fish species can be influenced by behaviour. Consequently, direct *in situ* methods have been developed to estimate the *TS* while fish are free and behaving normally in their natural environment. The *TS* measurements are normally made during trawling operations so that the measurements can be matched to the catch. However, the measurements of $TS \cdot kg^{-1}$ for horse mackerel taken during trawling were lower than those taken immediately prior to commencement of trawling. This was attributed to the fish diving to avoid the net, so

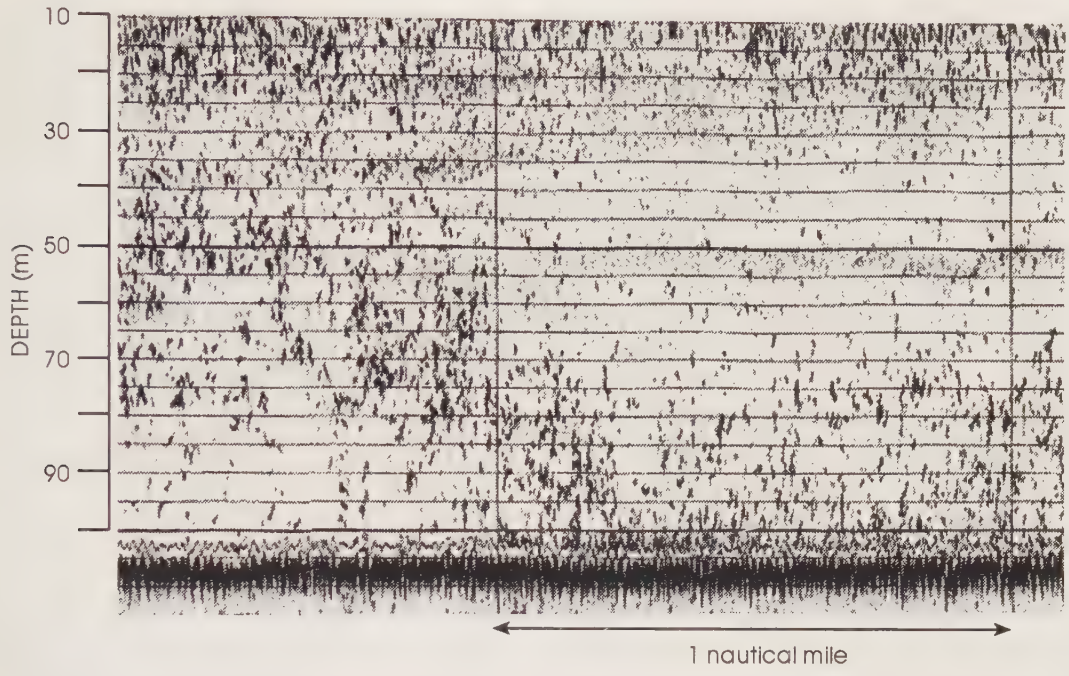

Fig. 4: Echo-chart showing individual targets of horse mackerel deeper than 40 m and the diving response to trawl deployment, which starts at the beginning of the 1 nautical mile marker

changing their tilt angle and the *TS* (Fig. 4). These results are important because they demonstrate the possible bias of *TS* measurements taken during trawling operations.

2.3 Demersal fish

RESEARCH on demersal fish continued to focus on assessment of the major commercial species. Although the Cape hakes remain the main target species of the offshore trawling fleet, there is a trend towards greater use of by-catch species, with increasing amounts of non-target species being landed. Demersal research is directed primarily at the two Cape hake species *Merluccius capensis* and *M. paradoxus*, the Agulhas sole *Austroglossus pectoralis* and the Cape horse mackerel. Research on other species of less commercial interest, such as the gurnard *Chelidonichthys capensis* and monkfish *Lophius vomerinus*, is also conducted, as well as on the now scarce, but still sought-after, kingklip *Genypterus capensis*.

The annual midyear assessment of the Cape hake resource depends on catch-and-effort statistics from the commercial trawl fisheries. Specifically, the information from the deep-water fleets is standardized and annual catch rate indices for the West and South coasts calculated. The indices for hake in 1992 were marginally higher than in 1991, indicating that hake abundance in both areas is still increasing (Fig. 5). The sustained recovery of the hake resource is maintained by applying a conservative harvesting strategy based on a dynamic surplus production model.

An important component of the hake stock assessment and research is the fishery-independent biomass assessment surveys conducted on board F.R.S. *Africana*. Estimates of the

hake biomass on the West Coast in January and on the South Coast in April/May and September are used to tune the production model. The 1992 biomass estimates confirmed the trend of a slow, but sustained, improvement in the hake resource evident from commercial data. Ongoing studies aim to re-evaluate the model used to assess the resource and also to look critically at the current harvesting strategy. Because of data constraints, the model in its present form assumes that the hake resource consists of a single species. Also, separate catch rate indices are used for West and South coasts (Fig. 5), presupposing the existence of two separate stocks.

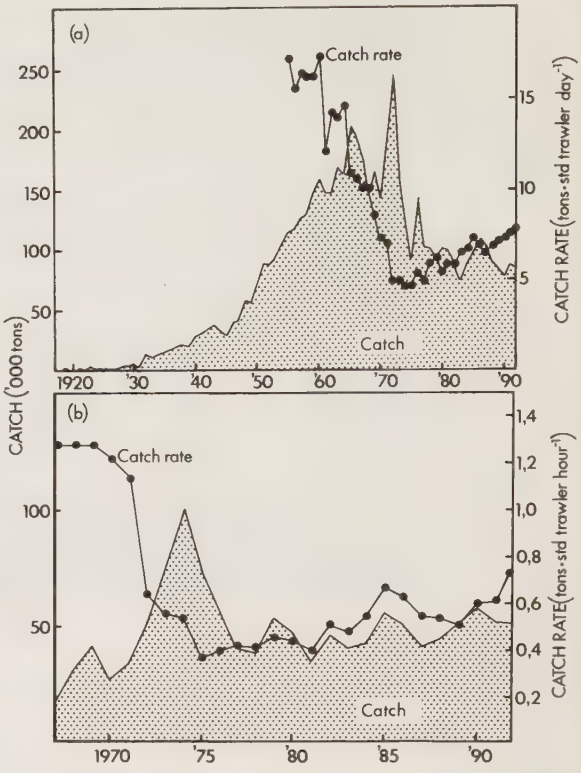

Fig. 5: Trends in hake catches and catch rates on (a) the West and (b) the South Coast of South Africa

Biomass estimates on the West Coast indicate a greater abundance of hake in winter than in summer, probably because of inshore/offshore movements of deep-water hake *M. paradoxus* in the 300–500 m depth range (Fig. 6). Survey results also show that the distribution of both hake species is depth-dependent. *M. capensis* is the dominant species in the 0–200 m depth range and *M. paradoxus* in water deeper than 300 m. A large portion of the *M. capensis* stock is found on the Agulhas Bank. Biomass estimates of *M. capensis* for the West Coast fluctuate from year to year. The possibility that these variations result from incursions of *M. capensis* from either the Agulhas Bank or Namibian stocks is currently being investigated.

An important and difficult problem tackled recently concerns improving the reliability and range of demersal surveys. Results from these surveys are extrapolated to include untrawlable grounds, thereby introducing some bias in the estimates of biomass. It has become clear that experimenting with the trawling gear in order to be able to work these difficult grounds is the best way to eliminate this bias. Several options are being explored and trawling experiments will be conducted in 1993.

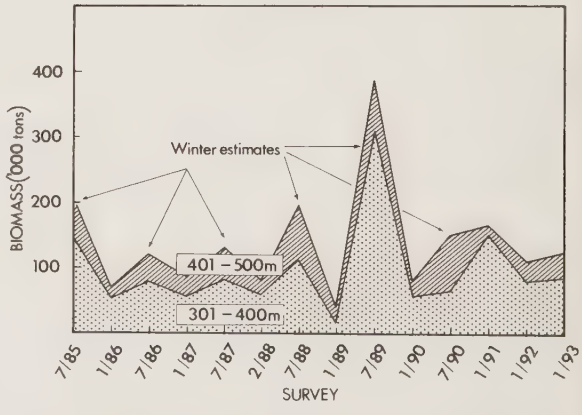

Fig. 6: Survey biomass estimates of deep-water Cape hake *Merluccius paradoxus* in the 300–400 m and 400–500 m depth ranges, showing inshore and offshore movements

Analyses of South Coast *M. capensis* stomach sample data have demonstrated the highly piscivorous nature of the Cape hakes there.

Cannibalism is evident in all size-classes, but its frequency of occurrence is most noticeable in the diet of fish greater than 50 cm total length. On the South Coast, interspecific cannibalism (between the two hake species) is lower than on the West Coast. Intraspecific cannibalism (within species) is, however, higher on the South Coast. This is thought to result from the differences in the spatial distribution of the various size-classes of Cape hake on the two coasts. The study has also shown that dietary composition changes with body size. Fish <60 cm long feed predominantly on pelagic fish, whereas bigger fish consume proportionately more demersal species. The study of diet has also provided some insight into the vertical migratory behaviour of the shallow-water Cape hake *M. capensis*. The lower consumption of anchovy by hake >60 cm compared to that by hake <60 cm suggests a change in behaviour. Smaller hake undertake more extensive vertical migrations than larger hake, so allowing them to consume a greater proportion of anchovy.

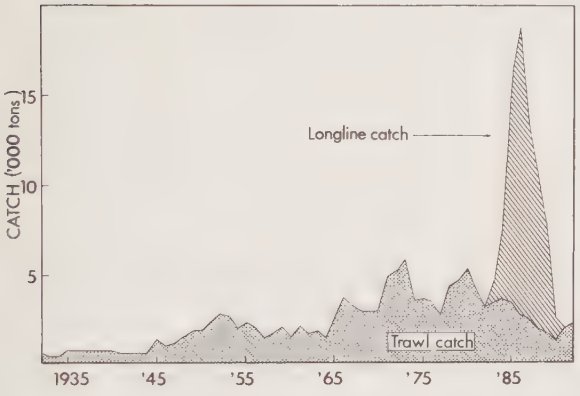

Fig. 7: Catches of kingklip in the hake-directed trawl fishery since 1932 and the longline fishery, showing the slight increase in the kingklip catches in the trawl fishery since 1991

The kingklip resource has not yet recovered from the intensive exploitation of the recent past. Since the cessation of longlining at the end of 1990, however, the by-catch of the species in the hake-directed trawl fishery has bottomed-out and perhaps slowly begun to increase (Fig. 7). There has been much pressure lately to introduce hake-directed longlining. This initially caused concern among Institute scientists, who were reminded of the unfortunate kingklip longlining history. Preliminary modelling, however, indicated that longlining could possibly be biologically preferable to trawling. A two-year research programme to establish the feasibility and desirability of longlining was proposed in order to provide sound, rational scientific advice on a possible future hake-directed longline fishery.

Research on Agulhas sole has concentrated on identifying factors causing fluctuations in sole catches on the South Coast and on the optimum mesh size for inshore sole-directed trawlers. The 75-mm mesh-size in use by the inshore fleet has been found to give the optimal selectivity curve and maximizes the stock-recruit relationship. The biology of the Agulhas sole has been studied with renewed effort, with the emphasis on reproductive biology. Nine spawnings have been recorded in captive sole between January and October. From ovaries of Agulhas sole collected during South Coast surveys, size at first maturity has been confirmed by histological analysis of the post-ovulatory follicles. Spawning localities have also been determined from the distribution of post-ovulatory follicles. It is evident that the size at first maturity decreases from west to east across the Agulhas Bank, but that it increases with depth. The relative abundance of juvenile sole has also been shown to relate directly to the extent of the muddy substratum found on the South Coast.

2.4 Linefish

THE National Marine Linefish System (NMLS) now contains a vast quantity of data. By the end of 1991, more than 824 000 individual daily catch and effort records had been entered onto the system, 72% from commercial catch returns and 20% from recreational competition returns, the oldest data being from 1967. It is the principal source of South African linefish catch and effort data and is increasingly used to produce a wide variety of summaries used by both researchers and fisheries managers.

At the second National Linefish Symposium in late 1992, one presentation described the South African tuna fishery and showed that the South Atlantic albacore *Thunnus alalunga* stock, on which the South African tuna fishery relies, is overexploited. The current level of exploitable biomass is estimated to be only 15% of its pristine level. In another presentation to the same symposium, it was shown, from analysis of red steenbras *Petrus rupestris* catch rates, that current bag limits are ineffective at protecting this species.

One of the most significant recent uses of the NMLS was to provide input into a complete reclassification of the Linefish Species Lists upon which all linefish management measures are based. Indices of species status were used to develop new "Critical", "Restricted", "Exploitable", "Recreational" and "Bait" lists, each with specific definitions and management criteria. These revisions, incorporated in the revised Sea Fisheries Regulations promulgated in August 1992, have resulted in important changes in linefish management measures, the most significant of which are:

- the promulgation of stringent restrictions on catches of species considered to be seriously threatened by overexploitation, such as white sharks *Carcharodon carcharias*, poenskop *Cymatoceps nasutus*, seventyfour *Polysteganus undulosus* and red steenbras;
- the replacement of the Open Species List with a Bait List, with resultant bag limits on non-commercial fishermen for all species, including such shoaling species as snoek;
- the recognition of specific groups of species targeted principally by commercial and recreational fishermen, and the development of different management objectives designed to protect the interests of both these groups.

Investigation of the value of marine reserves to protect linefish continued with the collection of information on catch rates and the census and tagging of fish in the De Hoop Marine Reserve and off Struis Bay. A further 1 205 fish were tagged in 1992, bringing the total tagged to 9 026. The main species tagged are Roman *Chrysoblephus laticeps*, santer *Cheimerius nufar*, red stumpnose *Chrysoblephus gibbiceps* and red steenbras, and 712 fish have been recaptured to date. The longest time at liberty was a Roman which remained in the reserve for 1 474 days and the longest distance travelled was a red steenbras that migrated almost 1 000 km from the reserve to the Mbashe River in Transkei. This study is providing information on the degree to which marine reserves protect stocks of reef fish, and the rate at which such fish move out to supplement catches elsewhere.

The tagging programme was also extended to investigate migration of white stumpnose *Rhabdosargus globiceps* between False Bay, Saldanha Bay and the offshore Agulhas Bank. Increasing line catches of this species off the South-Western Cape have raised questions concerning responsibility for the dramatic decline in this species between 1930 and 1960, and

the study is investigating the relative extent to which white stumpnose are caught by linefishermen and beach-seine or trawl operators. To date, 637 white stumpnose have been tagged, 402 biologically sampled and 1 203 measured. Initial results show that mean size and catch rates are both increasing steadily, suggesting that beach-seining and limited inshore trawling were primarily responsible for the past decline.

Much linefish research continued to be conducted by outside organizations under contract to the Institute:

- *Natal Recreational Data* (Oceanographic Research Institute ORI) — This ongoing contract continues to provide the main input of recreational data to the NMLS. ORI collected 27 431 recreational daily catch records, the main sources being skiboat, light-tackle and shore-angling cards. The Natal Parks Board provided further data for 5 622 shore patrols, totalling a distance of 43 558 km patrolled.
- *East Coast Gamefish and Natal Sparids* (ORI) — These two projects provided information on the biology and likely effective management options for Natal's most important sparid and gamefish target linefish species.
- *Kob Biology and Management* (Rhodes University) — Having determined the existence of two separate kob species in South African catches, this study concentrated on evaluating the extent to which various fishery sectors exploit the two species in different coastal regions.
- *Tsitsikamma National Park* (Rhodes University) — This project continues to investigate the role of the Tsitsikamma National Park in protecting important reef fish species in the southern Cape. Efforts concentrated on evaluating the rate of movements of eggs and larvae out of the reserve, as well as on the biology and ecology of a number of the shallower reef species.
- *South-Western Cape Shore-Angling Management* (University of Cape Town) — This project is investigating the effectiveness of current management measures used to manage shore-angling in the South-Western Cape. Results will be used to determine the value of marine reserves such as De Hoop, in comparison with traditional restrictions such as bag limits and closed seasons.
- *False Bay Beach-Seine Fishery* (University of Cape Town) — This study was initiated specifically to provide a scientific basis for solving many of the controversial arguments concerning competition between beach-seine nets and recreational fishermen in False Bay. Initial results are being used to revise permit conditions for beach-seine nets in the area, and indicate that many of the allegations concerning the effects of the nets on juvenile fish and benthic fauna are unfounded.

2.5 Squid

AS a result of a comprehensive review of the objectives for chokka squid research, a goal-orientated, integrated research programme has been designed, in which the following aspects are stressed:

- The need for a formal, structured management procedure for the resource, based on the results of an effective research programme which integrates physical and biological information, as well as stock assessment modelling approaches. Alternatives to the current closed season and effort limitation are being investigated.

- Recognition of the importance of environmental research in identifying the driving forces which cause squid stock size and availability to fluctuate. Two projects are in the early stages of providing conceptual models of the dynamics of the squid environment (i.e. studies of the inshore South Coast spawning grounds and the shelf feeding area).
- The contribution of biological studies towards understanding the life cycle of squid. The most important are those on age and growth, as well as reproductive studies on and adjoining the spawning grounds.

If the programme produces the results expected, a sound management approach and some elements of forecasting should be in place by 1996.

Following an exceptionally good year for catches in 1991, 1992 turned out to be the most unfavourable year for the squid-jigging industry since its inception in 1985, the total jig catch reaching only 2 600 tons (Fig. 8). The decline could have resulted from a reduction in stock size and/or reduced availability to the fishery. The biomass surveys carried out during the year did indicate an overall decline in the stock, but not to the extent suggested by the catches. It is therefore considered likely that squid were probably less available to the fishery than in most other years.

In searching for the cause of this lesser availability, environmental conditions in the region were examined. It is now evident that the very good catches in 1989 coincided with sea surface temperatures lower than average. However, average temperatures were recorded in 1992, indicating that environmental conditions other than temperature may also affect inshore spawning migrations and therefore catches. SCUBA diving has revealed that inshore spawning areas are adversely affected by conditions of heavy swell, causing the sanding up of these areas. Winter and spring 1992 were characterized by unusually heavy swells caused by continuous strong westerly winds, as evidenced by the erosion of many of the beaches on the South Coast. Squid may be adapted to avoiding conditions of high temperatures and heavy swell, and it is suspected that a large proportion of the stock may spawn deeper under such circumstances. Data collected in recent years from trawl surveys indicate that eggs are

Fig. 8: Chokka squid catches by fishery sector, 1978–1992

often deposited in depths up to 130 m, but the frequency of spawning in depths >50 m may increase under the conditions described above, causing a large but unknown part of the spawning stock to be unavailable to the jig fishery.

It is recognized that the ability of squid paralarvae to survive when hatched in deeper water is crucial to recruitment. The very wide distribution of paralarvae suggests that they are not confined to a narrow range of conditions.

Research has shown that specific sites exist for spawning; recent tagging studies have shown that squid may move rapidly among these sites. Spawning behaviour, egg survival and paralarval food availability are most likely to affect the choice of spawning sites, and therefore the numbers of squid there.

Investigating these and related problems contribute towards understanding fluctuations in catches; one of the major goals of the chokka squid research programme is to provide timely warning of these fluctuations.

2.6 Abalone

THE 1992/93 commercial abalone season appears to have been one of the most productive in recent years, according to reports from the commercial divers. Their season started a month earlier than that of the recreational fishery, in October 1992. *TAC*s were allocated to five coastal zones, and three were filled in the first month of the season. Indeed, within the first three months, 81% of the *TAC* of 605 tons had been landed. Due to the slow-growing nature of abalone and their essentially non-migratory behaviour, these improved catch rates are considered to have resulted most likely from favourable sea conditions, rather than marked stock improvements.

Monitoring recruitment cycles at four stations continues to indicate regular settlement east of Cape Hangklip, in both commercial grounds and the Betty's Bay marine reserve. In addition, unlike in previous years when the Robben Island site near Cape Town had intermittent settlement, annual settlement has been more regular since 1991, albeit at a low intensity.

The first telephonic polling of licensed recreational abalone divers showed a far higher effort than had been expected. In all, 27 278 permits were issued during the 1991/92 abalone season, and 800 of these permit-holders were interviewed telephonically at various stages of the season. From these results it was estimated that 368 tons were taken by recreational divers (Fig. 9), a mass equivalent to 62% of the commercial *TAC*. However, significant areas of the coastline (the West Coast, False Bay and Mas Bay) do not have commercial *TAC*s allocated, and certain commercial areas are unavailable to the public (Robben Island and Dyer Island), so that in areas where both sectors operated, the recreational take equalled approximately 37% of the commercial *TAC* allocated. The average landing per permit-holder equalled 20 abalone for the season.

2.7 Rock lobster

RATES of growth and production of West Coast rock lobster continued to be low on most fishing grounds in the 1991/92 fishing season. This resulted in industry achieving their worst catch rates on record. The *TAC* at the start of the season had been set at 2 715 tons, but midway through the season, it became obvious that this catch would be unattainable. In the

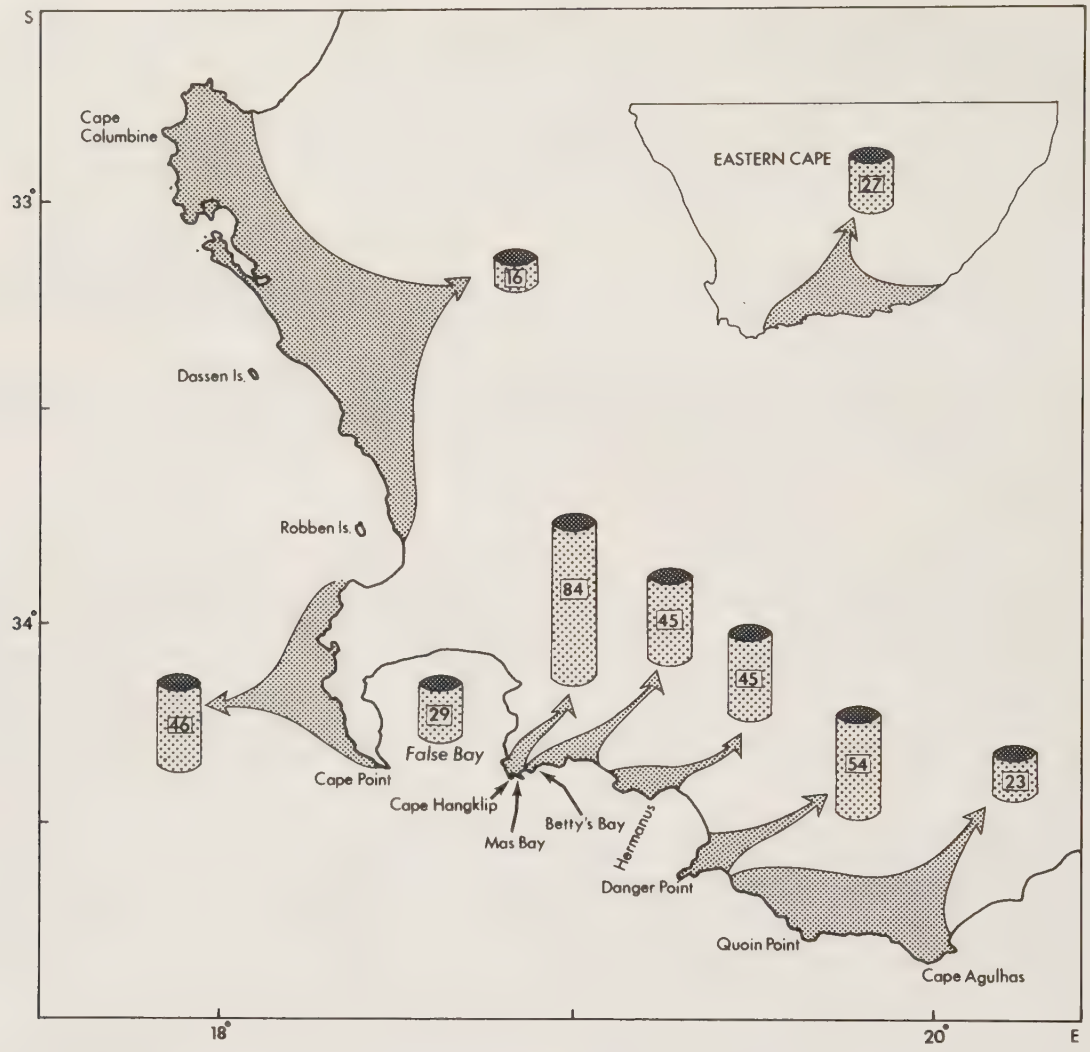

Fig. 9: Recreational abalone diver landings (tons) per coastal region deduced from the 1991/92 season telephone survey

light of this serious situation, the Minister of Environment Affairs decided, as a one-time socio-economic concession, temporarily to reduce the minimum size for lobsters from 89 to 75 mm, while simultaneously reducing the overall *TAC* to 2 400 tons. Intense scientific deliberation regarding the advisability of permanently changing the minimum size for West Coast lobster culminated in late 1992, with the Minister announcing the introduction of a new minimum size of 80 mm.

West Coast lobster *TAC* decisions for the 1992/93 season were, for the first time, based on the products of a mathematical model of the resource developed by a University of Cape Town scientist working under contract to the Institute. Although a permanent operational

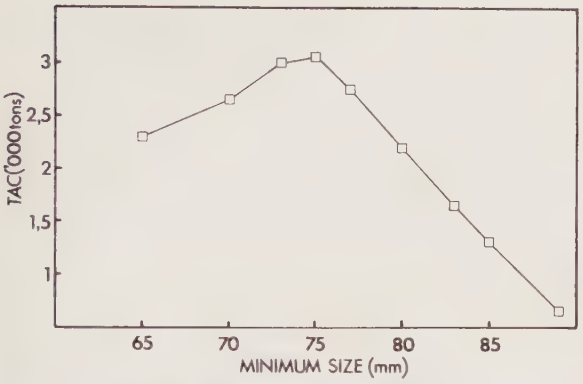

Fig. 10: Maximum *TAC* for West Coast rock lobster for 1992/93, for different minimum sizes, which do not violate the specified constraints. These constraints are that the *TAC* would not result in the fishery exceeding a 30% harvesting proportion or the egg production falling below 50% of the assumed pristine level, within the medium term, under a future growth scenario of that season and one more season of poor growth

management procedure has yet to be formulated for West Coast lobster, agreement to strive to maintain the levels of egg production by the population at 50% of the pristine level, and to ensure that the harvesting proportion does not exceed 30% of the available biomass, should contribute to optimal utilization of the resource (Fig. 10). However, persistence of the current low growth phase for a few more years could have disastrous consequences for the resource, the fishery and those who depend on it for their livelihood.

A fishery-independent monitoring survey (FIMS) was initiated at the start of the 1992/93 season to monitor the long-term effects of the change in lobster minimum size. The survey was conducted in four areas (Lambert's Bay/Elands Bay, Saldanha Bay/St Helena Bay, Dassen Island and Hout Bay/Cape Point), approximately 200 stations being chosen by means of a stratified random sampling approach and sampled in each area. The idea is that these same stations will be fished in future years in order to gauge any changes in lobster catch rates and population size structure that might occur. It is believed that the survey, together with the size composition information from industry catches (both unsorted catches at sea and landed catches) will provide valuable insight into the response of the lobster resource to the change in minimum size.

A telephone survey, introduced in the 1991/92 season, provided valuable information on the impact of recreational fishermen on the West Coast lobster resource. In all, 44 469 lobster permits were issued in 1991/92 and this resulted in an estimated recreational catch for that season of approximately 160 tons. In addition to demographic data relating to the sex, age and home language of permit-holders, information was also obtained on the extent to which various fishing methods were used by the public as well as what proportion of recreational fishermen are visitors to rather than permanent residents of the coast. The survey showed that most recreational fishing took place along the stretch of coast between Hout Bay and Cape Point (40%) and between Hangklip and Gans Bay (25%). The results of the 1992/93 telephone survey will be invaluable in assessing the response of the recreational lobster fishing sector to the reduction in the minimum size limit, coupled with the lengthening of the recreational fishing season by three months. Preliminary estimates indicate that these changes to the minimum size and fishing season have increased the impact of recreational fishermen substantially.

Field and laboratory research examining lobster biochemical composition as a possible predictor of growth in male lobsters continued in 1992/93. Analysis revealed that lobster abdominal muscle was unsuitable for the purpose, but that the biochemical composition (especially lipid content) of the hepatopancreas showed great promise in this regard. Both hepatopancreas mass and lipid content showed a clear cyclical pattern on a monthly and moult cycle basis. The two indicators peak during mid-intermoult and then decrease through the premoult phase to

reach lowest values immediately after moulting. Although at this stage the hepatopancreas lipid content conforms to all the prerequisites needed for a predictive index, its use as a predictor of male growth will only be confirmed by means of further field and laboratory research.

Monitoring of size composition, growth and movements of South Coast lobster *Palinurus gilchristi* has been intensified in recent years and the first steps towards modelling this resource by means of a surplus production approach are under way. Should the modelling approach prove to be successful, management of the resource may move away from what has become, for all intents and purposes, a constant catch strategy.

2.8 Seaweed

A STUDY has been initiated on the effects of harvesting kelp in the Danger Point area, where this brown seaweed is required for feed in two experimental abalone farms. On each side of the Danger Point peninsula, cut (experimental) and uncut (control) lanes have been established in the kelp. The study aims to determine rates of regrowth of the kelp, and any possible effects on plants and animals that live within the kelp bed. Effects of harvesting kelp on the natural populations of abalone are also monitored. Low-level commercial kelp harvesting at Soetwater on the Cape Peninsula has been monitored for more than a decade, allowing a Total Allowable Harvest (*TAH*) to be set for the first time. It constitutes <4% of the biomass of the whole kelp bed, less than the quantity estimated to be lost annually during storms.

Fig. 11: *Gracilaria* returns to Saldanha Bay. No beach-cast was obtained when the population of this seaweed collapsed at the end of 1988, but recovery began in 1992. Current research aims to understand these fluctuations

Gracilaria, the agar-producing red seaweed that sporadically has supported a small industry in the Saldanha Bay area since the 1950s, reappeared in large quantities during 1992 (Fig. 11). The natural population there had collapsed during 1988/1989 and only began to show signs of recovery at the end of 1991. Experimental transplants grew well throughout the year, maximum specific daily growth rates of more than 13% being obtained in summer, indicating the potential for rapid recovery of this economically important species. The aim of the study is to establish the causes of the enormous long-term fluctuations in the Saldanha *Gracilaria* population. Because large beach-casts of *Gracilaria* are now being obtained at St Helena Bay for the first time, that resource is also being investigated.

During 1992, ecological studies were conducted on several potentially useful carrageenan-producing red seaweeds, including *Gigartina radula* and *Gigartina stiriata*, and the annual yield of these species is estimated to be about 260 tons (fresh mass). Contract research in the Eastern Cape examined the effects of intensive harvesting of *Gelidium pristoides*, and harvesting of *G. abbottiorum* (formerly *G. amansii*). Results show that current collecting practices have very little effect on the resource.

* * *

3. Environmental and Ecological Studies

3.1 Red tide

THE problem of toxin-producing and otherwise harmful algae is a world-wide phenomenon, of concern to both cultured and wild fisheries, and to human health. A monitoring programme for red tides is conducted by the Institute as a service for those who use and enjoy the coastal zone. The monitoring is augmented by research to promote understanding and to improve the operation of the monitoring programme .

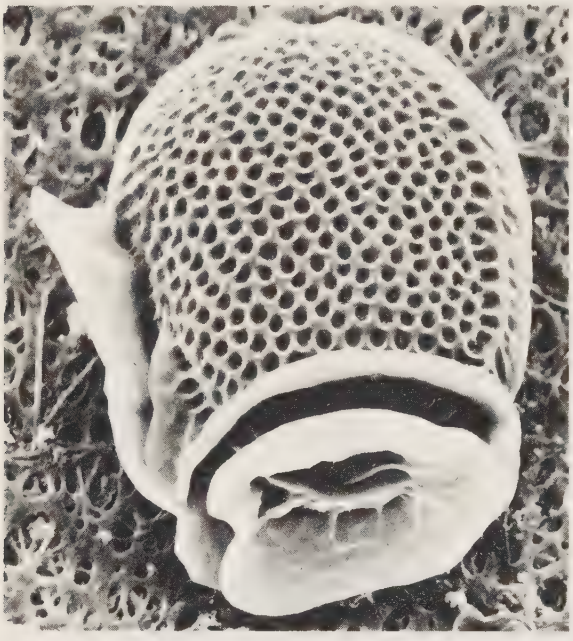

Fig. 12: Scanning electron micrograph of *Dinophysis acuminata*, the dinoflagellate responsible for Diarrhetic Shellfish Poisoning (DSP)

Diarrhetic Shellfish Poisoning (DSP), which was identified for the first time on the West Coast during autumn 1991 and on both West and South coasts during autumn 1992, again appeared on the West Coast during autumn 1993. Two methods of detection of DSP have been used: a commercially available immunoassay test kit and a mouse bioassay. The causative organism has been identified as the dinoflagellate *Dinophysis acuminata* (Fig. 12). The widespread occurrence of *D. acuminata* on the South African coast, the ability of low cell concentrations to render shellfish toxic, as well as the reported long duration of infestation, will not only impact on public health, but could restrict growth of the local shellfish industry.

As a result of the numerous queries concerning the status of red tide and the possible toxicity of shellfish, a telephone-in service [(021)439-4380] has recently been implemented to relay the information to the public. To further advance public understanding and cooperation a pamphlet entitled "Red Tide and Shellfish Poisoning" has been published and distributed.

Further progress has been made in relating red tides to the meteorology of the southern Benguela. The close coupling of red tides to seasonal upwelling, with a noticeable lull in both red-tide activity and upwelling in midsummer demonstrates the control of bloom development by wind-driven upwelling through the proximal agents of nutrients and light. At the event scale, red tides follow wind reversal associated with perturbations to the ambient upwelling winds by the approach of cyclonic systems and associated coastal low pressure cells. Interannual increases in red-tide activity have been related to the *El Niño*/Southern Oscillation. The operative mechanisms responsible for this increase include reduced ridging of the South Atlantic high and increased cyclonic perturbation resulting in weaker longshore and increased onshore winds.

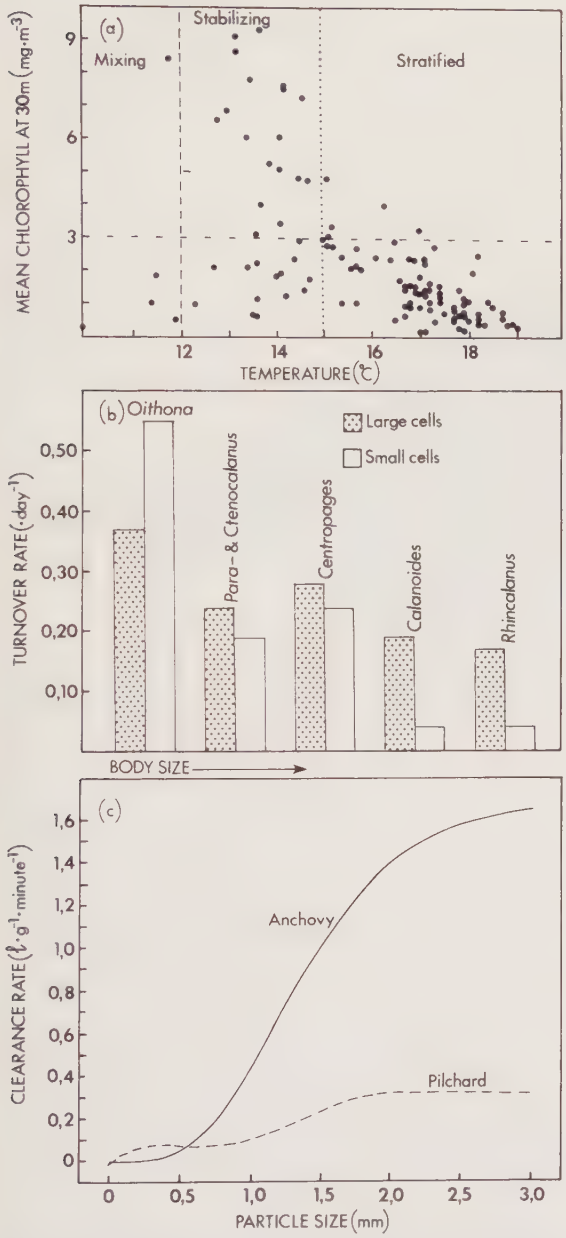

Fig. 13: Plankton-fish interactions — (a) relationship between sea surface temperature and mean concentration of chlorophyll *a* in the upper 30 m over the West Coast shelf, (b) effects of food particle size on the turnover rate (from the combined juvenile growth and female fecundity) of small and large copepods on the West Coast, (c) predicted weight-standardized clearance rate of anchovy and pilchard as a function of food particle size

3.2 Plankton-fish trophic interactions

IN marine ecosystems, the size structure and biomass of a phytoplankton population are closely related to the hydrodynamics, which are driven by various physical forces. Stability of the upper layers is the major factor controlling phytoplankton productivity, mediating both nutrient and light availability for phytoplankton growth.

In the southern Benguela, sea surface temperature may be used as an index of both stability and the degree of nutrient enrichment of the upper layers. Under prolonged mixing, temperatures are low (< 12°C), and light-limitation suppresses the development of large phytoplankton populations, despite enhanced nutrient enrichment. Under intermittent mixing, temperatures are intermediate (12–15°C) and nutrient enrichment of the euphotic zone is maintained, promoting the development of high-biomass populations (> 3 mg chlorophyll $a \cdot m^{-3}$) dominated by large cells or chain-forming diatoms. When conditions stabilize, temperatures may rise to in excess of 15°C, and nutrient depletion of the upper layers may retard phytoplankton production. Under these conditions the phytoplankton is typically dominated by small species of flagellate (Fig. 13a).

The composition of the phytoplankton assemblage influences the structure of the zooplankton community. Copepods, which dominate the zooplankton in terms of number and biomass, appear to prefer food particles of a particular size range or species. Their rates of ingestion are highly variable, and *in situ* measurements indicate that responses differ according to food particle size and the relative body size of different copepod species. Large copepods, such as *Calanoides* and *Rhincalanus*, exhibit considerably higher rates of ingestion of large cells (> 15 µm) than small cells, suggesting inefficient feeding on small particles. Smaller copepods, however,

display similar rates of ingestion when offered both small or large cells. These observations are mirrored in the specific growth rates of copepods (Fig. 13b). Whereas growth of *Calanoides* and *Rhincalanus* is very sensitive to particle size of their food, smaller copepods (*Centropages*, *Paracalanus* and *Ctenocalanus*) tend to be indifferent towards particle size or may even show a preference for smaller food particles (e.g. *Oithona*).

The size spectrum of the planktonic food environment has profound implications for the structure of the pelagic foodweb at higher trophic levels. Studies of the feeding behaviour of planktivorous fish, such as anchovy (predominantly a size-selective particulate feeder) and pilchard (predominantly a non-selective filter-feeder), show that pilchard are more efficient than anchovy at removing particles of <580 μm maximum dimension, whereas anchovy show markedly higher clearance rates on particles larger than this (Fig. 13c). This difference in clearance rates over the food size spectrum provides clear evidence for resource partitioning between these two species.

It can be concluded tentatively that long-term fluctuations of anchovy and pilchard, which have been observed over the past few decades in the Benguela ecosystem, are associated with structural changes in the ecosystem's phytoplankton and zooplankton assemblages. These in turn result from documented changes in the prevailing physical environment.

3.3 Fish behaviour

IN February 1992 the first attempt was made to use direct measurements of acoustic target strength to study the composition and vertical structure of fish communities on the West Coast shelf. The way to this technique was opened by the local development of software for the reliable recognition of single-fish targets. The acoustic technique has many advantages over traditional net-sampling, the chief of which are the far greater spatial extent of the sampling and the freedom from net selectivity. The target strength information permitted the species composition and vertical structure of multispecific communities consisting of juvenile hake (the predominant species), adult round herring *Etrumeus whiteheadi*, juvenile anchovy, pelagic goby *Sufflogobius bibarbatus*, horse mackerel and ribbonfish *Lepidopus caudatus* to be elucidated. An example is provided in Figure 14.

The water column is dominated by a peak around −49 dB in the upper 30 m and a secondary one around −57 dB at about 30 m, arising from juvenile hake and anchovy recruits respectively. Below this the targets increase in size but decrease in abundance towards the bottom, where they are mainly hake and horse mackerel. Apart from its use in elucidating community structure, the information on target strength of anchovy, hake, round herring and horse mackerel obtained in this study is invaluable in making acoustic stock estimates for these species.

The feeding behaviour of juvenile hake has been studied at two sites off the West Coast by combining acoustic observations of abundance and vertical distribution with information on prey availability obtained from nets. At the one site, hake fed preferentially on relatively large crustaceans. At the other, which was dominated by anchovy recruits, hake fed only on fish prey, small hake (10–25 cm) migrating upwards to feed on anchovy near the surface and larger hake remaining near the bottom and feeding cannibalistically. These observations demonstrate the importance of vertical migration in the foraging strategy of juvenile hake, and the need to be aware of such behaviour in acoustic or trawling surveys of these fish.

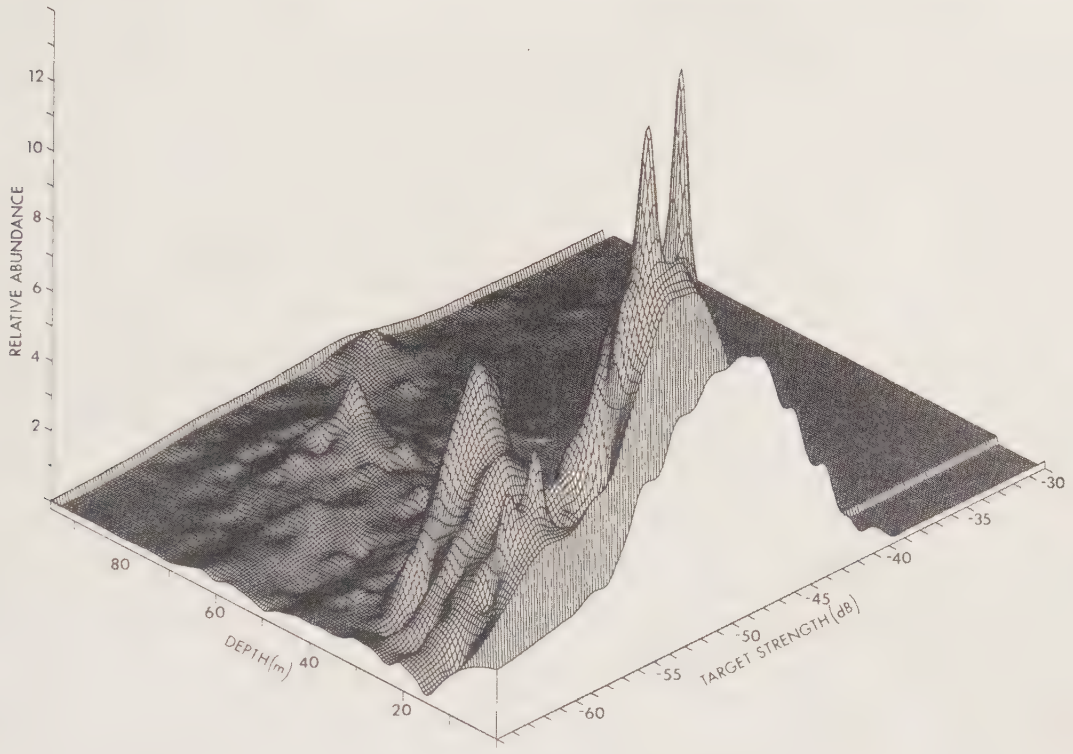

Fig. 14: Three-dimensional image showing the relationship between target strength and depth at night off the West Coast in February 1992. Peaks in the upper 30 m reflect a population of juvenile hake feeding on anchovy recruits

3.4 Mariculture-environment interactions

A SCIENTIFIC programme on the interactions between mariculture and the environment has recently been implemented. The objectives of the programme include: development of a system model which, coupled to a farm-scale model, will provide a quantitative carrying capacity and stocking density for intensive farming of mussels *Mytilus galloprovincialis* and *Choromytilus meridionalis* in Saldanha Bay; development of objective criteria to identify the most suitable areas for such an activity in Saldanha Bay and other potentially suitable systems; formulation, in conjunction with the industry, of a draft policy document on the principles for an environmentally based management strategy for mariculture in South Africa. Completion of this work will provide the industry with objective environmental criteria by which to maximize production and will ensure that the Bay is being used to best advantage.

It is expected that, for intensive mussel-farming, the factor limiting carrying capacity will be the availability of planktonic material and not the impact on water quality which is more typical of intensive fin-fisheries. The scientific programme therefore addresses the interaction between phytoplankton dynamics, nutrient and carbon cycling and the physics which drives the Bay circulation and flushing. This system-scale work is coupled to a farm-scale study of the

relationship between mussel growth rates and food supply dynamics as well as the impact of organic loading on the benthic community structure. The programme encompasses a holistic interdisciplinary strategy and an inter-institutional cooperative approach, and it will provide the first interim estimate of mussel carrying capacity for Saldanha Bay by the end of 1993.

A monitoring station has been in operation in the vicinity of one of the mussel farms since August 1991. This station, which currently relies on the collection of daily samples, will shortly be automated with hourly recordings of temperature, salinity and oxygen in the surface and bottom layers. The monitoring station has already improved understanding of the interactions giving rise to potential water quality problems. An example is provided by examination of the variability of oxygen within the bottom layer (Fig. 15).

In both 1992 and 1993, oxygen concentrations reached a minimum during the first quarter of the year, and in both cases the minima corresponded to a period in which three factors interacted simultaneously: discharge from pelagic fish factories, the prevalence of calm sunny

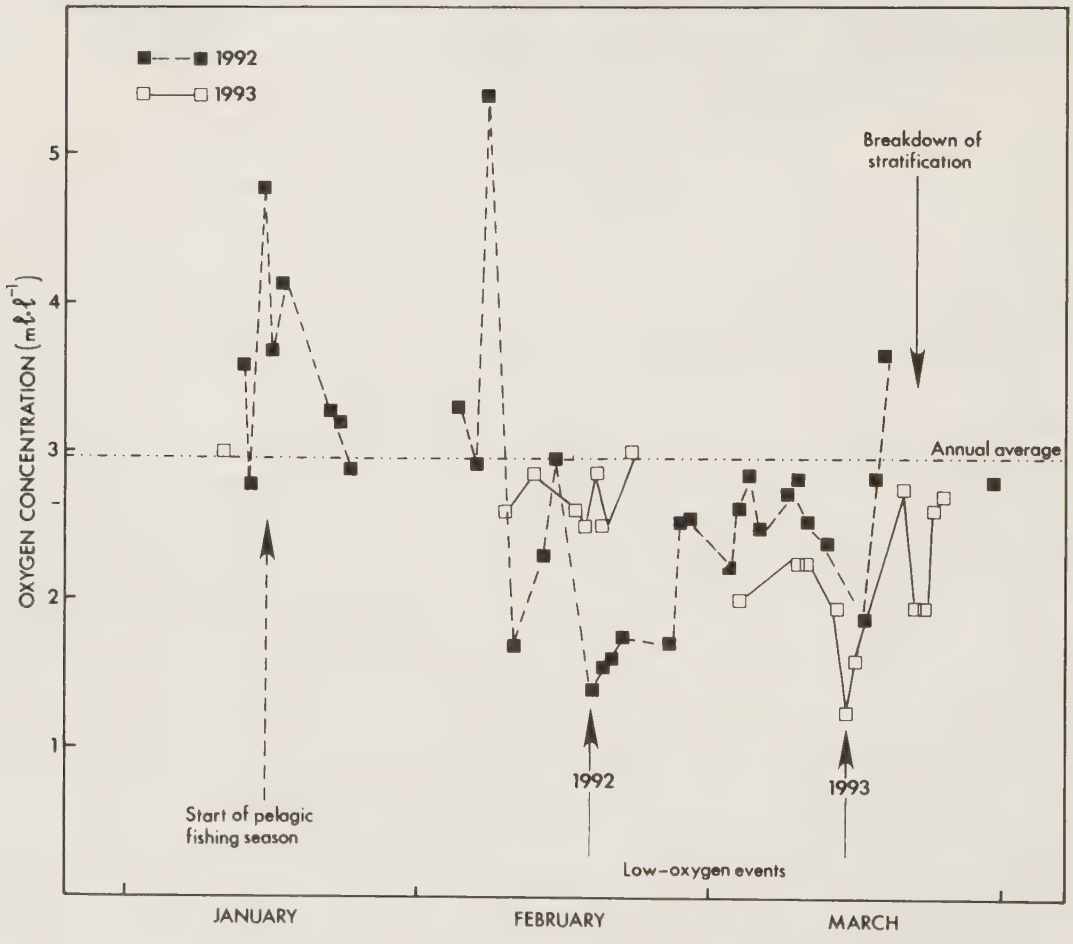

Fig. 15: Oxygen concentrations in the bottom mixed layer of Saldanha Bay

conditions, and water-column stratification. These findings enable models which simulate these processes individually to be coupled and matched against real data, so providing greater confidence in their predictions. It is evident that existing rates of fish factory discharge contribute significantly to the risk of low oxygen events by decreasing the number of calm days which are needed to reduce the oxygen concentration to <2 m$\ell \cdot \ell^{-1}$. This risk assessment approach might prove worthwhile in other natural high-risk areas on the West Coast.

3.5 Marine mammals

THE recovery of the South African fur seal from 300 years of overexploitation is one of South Africa's conservation success stories. However, fishermen may hold different views, for the estimated size of the seal population today is in the region of 1,5–2 million animals and apparently still growing. Unfortunately, because there are no estimates of the number of seals before exploitation began, it cannot be said whether the present population is still below, or perhaps already above, its original size. The latter situation is not inconceivable, given the development and expansion of some very large mainland colonies from the 1940s. The question arises, then, as to when the population will stabilize and at what level.

One of the important factors controlling the growth of any mammal population is infant mortality. This aspect of seal biology had, up to now, not been studied in South Africa because it is very time-intensive. However, a project to investigate pup mortality was started in 1991 at the mainland colony of Kleinsee. A study area was marked out and daily observations of pup deaths were made throughout the breeding season. Two years of data are now available and indicate that mortality among very young pups (<2 months old) may be substantial (21–30%, Fig. 16). It is also apparent that there may be considerable variation in the extent of pup

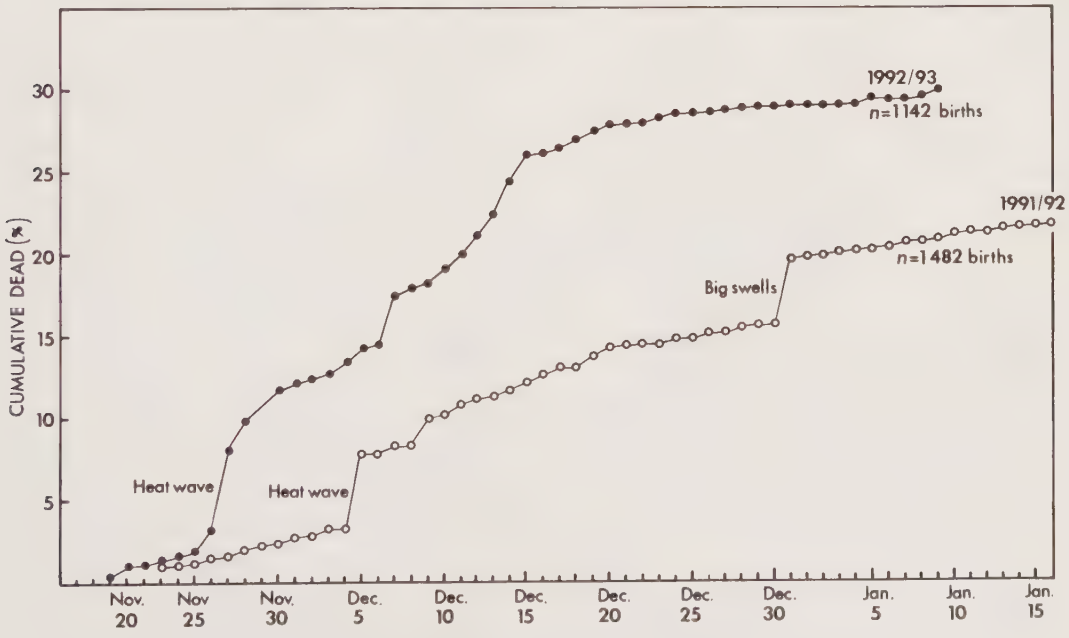

Fig. 16: Seal pup mortality at Kleinsee during 1991/92 and 1992/93

mortality between one year and the next. Extreme heat cannot be tolerated by the pups when they are too young to swim and high temperatures can therefore be a major cause of deaths. Information such as this is vital in improving the predictive power of computerized models of the seal population.

3.6 Seabirds

A CONTINUING rapid decline in numbers of African penguins, a species endemic to South Africa and Namibia, and Africa's only extant penguin, is a major cause for concern. It is likely that Dassen Island alone supported more than a million penguins as recently as 1930. By the 1950s the world's population of African penguins was estimated to have decreased to 570 000 individuals, and by the 1980s to only 160 000. Recent surveys suggest a further decrease to just 120 000 birds in 1992, largely as a result of a massive decrease at Dyer Island, which was the most populous breeding locality in the mid 1980s.

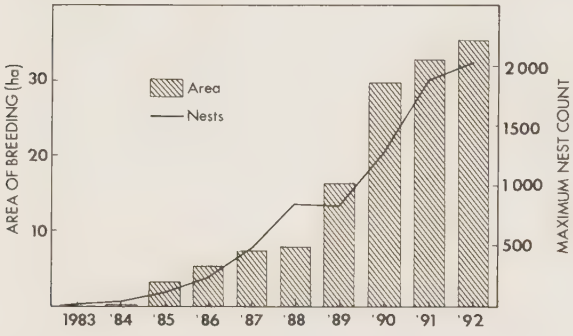

Fig. 17: Growth of the African penguin colony at Robben Island, 1983–1992

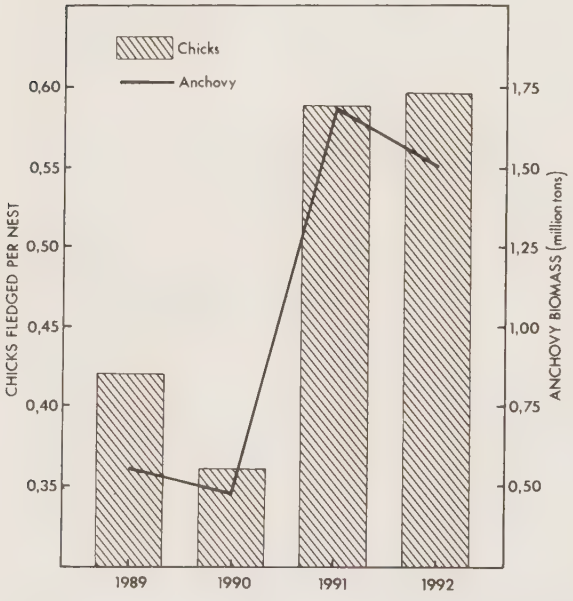

Fig. 18: Numbers of African penguin chicks fledged per nest at Robben Island contrasted with acoustic estimates of the biomass of anchovy, the main prey of penguins at the island, 1989–1992

In pleasing contrast to this gloomy overall scenario, Robben Island, near Cape Town, was recolonized by African Penguins in 1983, and the colony there has since expanded rapidly (Fig. 17). Penguins were abundant at Robben Island at the time of settlement of the Cape Colony by Europeans in the 1600s, and records indicate that they continued to breed at the island until about 1790. Reasons for their return after an absence of nearly 200 years are of interest. Robben Island was one of three "new" colonies formed in the Cape Town vicinity in the 1980s, so clearly penguins were seeking alternative breeding localities at that time. Common to all three sites when they were colonized was the presence of large numbers of other seabirds and an abundance of shade provided by vegetation or boulders. In 1992, 99% of the penguin nest sites at Robben Island were shaded, mostly by vegetation, but in spite of this large numbers of penguins still abandon nests during the hot summer months.

Penguins have a high mate fidelity at Robben Island. Banding has indicated that 94% of study birds have had just one mate; the first partner of some of those recorded

with two mates died. However, site fidelity is relatively low, 61% retaining the same site in contrast to the 78–89% at the crowded St Croix colony. Clearly space is not yet limiting at Robben Island.

The numbers of chicks fledged per nest at Robben Island is significantly related to acoustic estimates of anchovy biomass, the main prey of penguins at the island (Fig. 18). This indicates that penguins are likely to be influenced substantially by the selection of management measures for the anchovy resource.

3.7 Agulhas Bank productivity

EACH November, the survey of adult pelagic fish has revealed high concentrations of phytoplankton and large copepods on the eastern parts of the Agulhas Bank. In particular, a copepod population is centred over a subsurface ridge of cool water which extends from the coast between Knysna and St Sebastian Bay south-west for 100–200 km. Recent current measurements indicate cyclonic (clockwise) circulation around the ridge, so enabling the plankton populations to maintain themselves above this ridge while still being able to utilize the primary productivity resulting from continuous nutrient enrichment of the water column. The distribution of anchovy, pilchard and round herring over the Bank appear to respond to this ridge both positively and negatively: positively as a source of food, but negatively in that they tend to avoid the coolest waters (< 17°C) by spawning on the outside of the ridge, where eggs and larvae are often subject to greater offshore loss as a result of the proximity of the Agulhas Current.

In January 1992, an additional survey extended farther east and concentrated on the shelf-edge processes. It was undertaken to examine the influence of the Agulhas Current on hydrological and biological events on the Bank itself. In addition to the cool ridge already mentioned, this cruise found surprisingly high productivity farther east between Tsitsikamma and Port Alfred on the narrowing shelf (Fig. 19), resulting from upwelling created by the

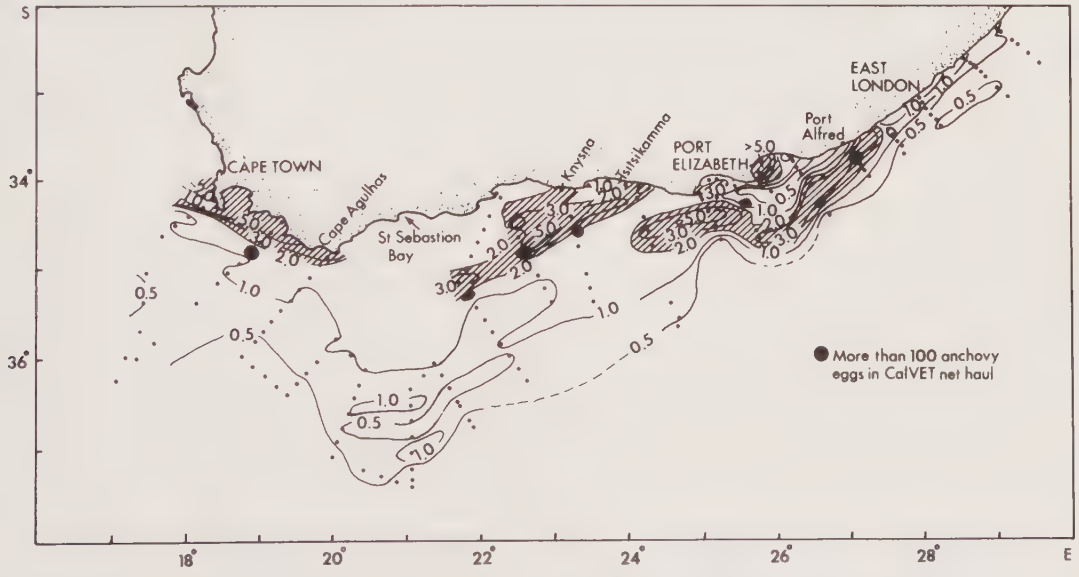

Fig. 19: The distribution of chlorophyll *a* ($mg \cdot m^{-3}$) and peak anchovy spawning areas during the Agulhas Bank Boundary Processes cruise of January 1992

Agulhas Current leaving the coast in a series of meanders. This also created an area of high hydrological and biological variability in the vicinity of Algoa Bay.

Along the outer edge of the Agulhas Bank, the variable flow patterns created by the Agulhas Current eddies apparently uplift nutrient-rich water at the shelf-break, resulting in doming of isotherms and isolated patches of high phytoplankton productivity.

These sources of nutrient-enrichment result in high phytoplankton productivity on the central and eastern Bank for much of spring and summer, as can be seen in Figure 19. This contrasts with typical temperate scenarios found on the western Bank (excluding nearshore), where the availability of nutrients and higher productivity clearly follow the stabilization of well-mixed winter conditions in spring, with a decline in summer.

3.8 Southern Ocean

THE Institute continues to carry out research on Antarctic krill. Significant developments included the first documented attempt to assess within-aggregation structure acoustically and the statistical analyses of aggregation distributions in space. The results of these analyses have contributed greatly to the work of the international Commission for the Conservation of Antarctic Marine Living Resources and its attempts to improve available indices (both fisheries- and survey-based) of krill abundance. The techniques developed to examine within-aggregation structure also have considerable importance for ongoing efforts to assess the structure of commercially important fish shoals around the South African coast. Analyses are continuing on a large data set obtained during various German acoustic surveys of krill in the West Atlantic. Plans are well advanced for future cooperative studies in the field with British scientists during 1994.

A member of the Institute's research staff was awarded a travel fellowship from the Royal Society in London to undertake cooperative research on krill aggregation with colleagues at the British Antarctic Survey in Cambridge. Much of the work undertaken during that visit was incorporated into the results reported above.

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4. SOME TECHNOLOGICAL ADVANCES

4.1 Measuring ocean currents

THREE approaches to the measurement of ocean currents around South Africa have been adopted. These are moored current-meter arrays, radio-tracked drogues and ADCP (acoustic Doppler current profilers) hull-mounted on research ships. Tracking of drogues is no longer practised because it is extremely labour-intensive and the mooring of current meters is no longer an option because of the prohibitive cost of foreign-made hardware. In addition, neither moored current meters nor ADCP are reliable in estimating currents in the upper 10 m, a part of the water-column thought to be important in the dispersal of the early life stages of some commercial fish species. Both these problems have been addressed, with some exciting results.

To obviate the high cost of importing equipment, the feasibility of designing an instrument in-house with a view to the manufacture of component parts under local contract was examined. A design based on similar units produced overseas was formulated. A stock of some 50 units with expansion to 100 at a later date is now envisaged. The anticipated cost is R8 000 per unit.

The prototype unit is nearing completion and will be tested against similar units shortly. The electronics was designed completely in-house and is approximately one-third the size of a similar imported equivalent. The method of sensing rotation is novel, using a small flux-gate compass mounted on a gimbal and allowing 30° attitude movements. An eight-month deployment period, sampling once per minute, is catered for, the data being recorded on a solid-state memory. The data can be extracted directly in engineering units so that no elaborate translation software is required. The unit is powered by just two small lithium batteries; consequently, the electronics fits into a small housing inside a short, strong stainless-steel cage, a plus factor at deployment time.

The casing is made either of high density polyethylene (HDPE) for depths less than 1 000 m or stainless-steel for depths up to 6 000 m. The HDPE unit is light enough to be picked up in one hand and requires very little flotation. The estimated cost of the HDPE unit components is R2 500 (U.S. $800 in mid 1993), with an additional R2 000 for the stainless-steel version.

Following three years of developmental work, a new method has been derived for the measurement of surface currents. The method, generally known as "feature-tracking", requires obtaining a field of advection vectors by following the movement of small thermal features in pairs of satellite sea surface temperature images. Tests have shown that, with this method, surface currents may be obtained to a precision of 6–8 $cm \cdot s^{-1}$ in speed and about 12° in direction. A major advantage of the procedure is that a synoptic picture of the surface circulation pattern may be obtained over large areas extending hundreds of kilometres from the coast. This often helps to identify those large-scale processes which influence the shelf environment. Application of the method is, however, restricted to periods of sustained cloud-free conditions.

4.2 Acoustic technology

DURING the course of the year the Institute's new micro-computer based Acoustic Integration and Data Analysis (AIDA) system was put into service on F.R.S. *Africana*, replacing the mini-

computer-based echo-integrator used on the vessel since 1983. AIDA has very high resolution in both horizontal and vertical directions, and having been developed in-house, is more versatile and adaptable than any commercially available echo-integrator. The system incorporates software for calibrating echo-sounders by sphere, and for determining acoustic target strength *in situ* from phase and amplitude information received from a split-beam transducer. The basic echo-integration and target-strength software is complete, but more elaborate software for analysing shoal structure acoustically, and for extracting and archiving other fine-scale density information, is still being developed. An improved method of isolating echoes from single fish in high-density situations, by means of phase-comparison techniques, is also being developed so that *in situ* target-strength estimates can be obtained from denser aggregations than is possible at present.

As a completely different approach to acoustic stock-assessment, the Institute is developing, in conjunction with outside contractors, a high-frequency, multi-beam echo-counter, code-named ABACUS (Advanced Beam-former for Acoustic Counting of Underwater Scatterers). ABACUS will use digital beam-forming techniques to generate a swath of narrow receiving beams in the direction of travel. These will intersect with a narrow transmitted beam to create a receiving system with a resolution anticipated to be high enough to count individual fish in dense sound-scattering layers at night. From these counts it should be possible to estimate density, providing an alternative to echo-integration, with the great advantage that it would not be necessary to know the target strength of the fish. Alternatively, the density estimates obtained from ABACUS could be used to calculate average target strength from echo-integrator data collected simultaneously. A computer model of the scattering and beam-forming processes has given encouraging results, and has enabled the hardware design to be finalized. A start has been made on the construction of a prototype receiver.

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5. PUBLICATIONS

THE 172 original works listed hereafter in which the Sea Fisheries Research Institute was involved in 1992 are on par with the 178 in 1990 but much lower than the record 222 in 1991. In both 1990 and 1992 a single number of the *South African Journal of Marine Science* was produced, whereas there were two in 1991. In all, 82 contributions to the Benguela-91 symposium in Cape Town (*Benguela Trophic Functioning*) that had passed peer review were published in 1992 as No. 12 of the Journal, a number that was co-edited by three overseas participants to the symposium and the usual editor. This bumper crop eclipsed not only the 32 papers of Journal 9 (1990), but also the combined total (72) of Journals 10 and 11 (1991). In comparing totals it must be borne in mind that there is some overlap between 1991 and 1992 because advance abstracts of 65 oral and poster presentations with staff involvement at Benguela-91 were already listed in 1991, boosting non-SFRI local publications for that year to 100, whereas only 49 are listed for 1992, including one M.Sc. and three Ph.D. theses. Staff participation in papers overseas in 1992 was 31.

An informative booklet, *Treasure Chest of the Sea/Skatkis van die See*, sponsored by a fishing company, was compiled for National Marine Day by two staff members from seven contributions by staff and one from a non-SFRI local scientist. Finally, two staff researchers wrote the book *Secrets of the Sea/Geheime van die See*. It was published locally and separately in both official languages and is aimed at High School and advanced Junior School level. New illustrations were added, but the colour plates of *Oceans of Life off Southern Africa*, edited by them in 1989, were retained.

Of the 172 works listed, 77 were by staff members only and 50 by outside colleagues publishing in the house series, the remainder being cooperative ventures. In all, 208 different authors (74 staff, 76 other local and 58 overseas) participated in the publications.

5.1 Publications involving staff and directly contracted staff

AGENBAG, J. J. 1992 — A procedure for the computation of sea surface advection velocities from satellite thermal band imagery, with applications to the South East Atlantic Ocean. Ph.D. thesis, University of Cape Town: [vi] + 394 pp.

ANDERSON, R. [J.] 1992 — Armoured seaweeds – the coralline algae. *Underwater* **20**: 30–31.

ANDERSON, R. [J.] 1992 — Seaweeds. In *Treasure Chest of the Sea*. Van der Vyver, I. and E. Sutherland (Compilers). Cape Town; Chief Directorate Sea Fisheries: 16–17.

ANDERSON, R. J., LEVITT, G. J., DAWES, C. P. and R. H. SIMONS 1992 — Restocking and cultivation of *Gracilaria* in the Western Cape. Conference on Aquatic Ecosystems, Cape Town, July 1992. Cape Town; Southern African Society of Aquatic Scientists and the Phycological Society of Southern Africa: p. 15 (Paper Abstract).

ANDERSON, R. J., LEVITT, G. J., DAWES, C. P. and R. H. SIMONS 1992 — Experimental growth of *Gracilaria* in Saldanha Bay, South Africa. Proceedings of the 1st International Workshop on Sustainable Seaweed Resource Development in Sub-Saharan Africa, Windhoek, Namibia, March 1992. Mshigeni, K. E., Bolton, J., Critchley, A. and G. Kiangi (Eds). Windhoek; K. E. Mshigeni: 19–36.

ANDERSON, R. J., LEVITT, G. J. and D. W. KEATS 1992 — The role of herbivores in the collapse of the *Gracilaria* resource at Saldanha Bay, South Africa. XIVth International Seaweed Symposium, Brittany, France, 1992: p. 54 (Abstract).

ANON. 1991 — An investigation into the causes of the recent fluctuations in pelagic fish stocks off South Africa. Unpublished Report, Sea Fisheries Research Institute, South Africa: 8 pp. + 18 Figures (mimeo).

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